UNITED STATES PATENT APPLICATION

for

COAXIAL RADIO FREQUENCY ADAPTER AND METHOD

Inventors:

Doug Kreager

Perla Redmond

Kevin B. Redmond

Prepared by:

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN
12400 Wilshire Boulevard
Seventh Floor
Los Angeles, CA 90025-1026
(408) 720-8300

Attorney Docket No.: 42P13108

Coaxial Radio Frequency Adapter and Method

Background

There are many environments which require that a transmission loss be small, characterizable, and/or predictable. For example, in a system for performing a production test on a radio frequency (RF) device under test (DUT), an RF test probe may be used to contact the DUT. The DUT may for example be an integrated circuit board for a wireless communication device.

As shown in Fig. 1, DUT 2 may be placed in RF test fixture 4. RF probe 6 may be mounted in RF test fixture 4 in a position to contact DUT 2. RF probe 6 may be connected by coaxial cable 5 and coaxial cable 3 to RF equipment rack 9. RF equipment rack 9 may include a signal generator 11, a switch 13, a spectrum analyzer 15, and a test controller PC 17. In Figure 1, coaxial cable 5 is shown in electrical communication with switch 13 through coaxial cable 3. Test controller PC 17 may connect coaxial cable 5 through switch 13 to spectrum analyzer 15 in order to measure the RF transmitting power of DUT 2. Alternatively, test controller PC 17 may connect coaxial cable 5 through switch 13 to signal generator 11 in order to measure the RF receiving sensitivity of DUT 2.

Such measurements may be made during production runs of DUT 2 for quality control purposes.

Brief Description of the Drawings

Figure 1 illustrates a production test configuration used to evaluate a device under test.

Figure 2 is an exploded view of an adapter in relation to a radio frequency probe and a coaxial cable.

Figure 3 is an exploded close-up view of the adapter of Figure 2.

Figure 4 is a close-up top view of the adapter of Figure 2 in unexploded form.

Figure 5 is a close-up bottom view of the adapter of Figure 2 in unexploded form.

Figure 6 is a cross-section view of the adapter of Figure 2 in press-contact with a radio frequency probe.

Figure 7 is a cross-section view of the adapter of Figure 2 in press-contact with a radio frequency probe and in screw engagement with the sub-miniature assembly connector of a coaxial cable.

Figure 7a is an enlarged view of part of Figure 7.

Figure 8 is a top view of the adapter mounted onto a fixturing block.

Figure 9 is a bottom view of the assembly of Figure 8.

Figure 10 shows the assembly of Figure 8 in contact with an RF test fixture, an RF test probe, and a coaxial cable.

Figure 11 illustrates a calibration configuration.

Figure 12 illustrates a testing configuration for characterizing losses in a system with a test fixture.

Detailed Description of the Preferred Embodiment

Figure 1 illustrates a production test configuration used to evaluate DUT 2. Because the production test configuration may be used to measure RF characteristics associated with DUT 2, the inventors desire to know the extent of RF signal loss associated with the test equipment itself.

A vector network analyzer can be used to evaluate RF signal loss through a closed circuit. For example, a closed circuit including RF test probe 6 but not including any device under test could be evaluated. Typically, RF test probe 6 can be easily connected at one end to a coaxial cable. The other end (the "contact end") of RF test probe 6, however, is meant for press-contact with DUT 2 and cannot easily be connected to a coaxial cable. For example, the contact end may be spring loaded so that the test probe is urged against DUT 2. The contact end may have a sharp crown edge. An adapter of the present invention may be used to connect the contact end of RF test probe 6 to a sub-miniature assembly (SMA) connector of a coaxial cable.

Figure 2 is an exploded view of adapter 7 in relation to RF probe 6 and coaxial cable 8. Adapter 7 is devised to electrically connect RF probe 6 to coaxial cable 8 with no change in impedance and no reflections. Adapter 7 includes adapter ground sleeve 14 and adapter signal pin 12. Adapter signal pin 12 fits inside of adapter ground sleeve 14. Adapter signal pin 12 may be spaced apart from adapter ground sleeve 14 by a dielectric material surrounding at least part of adapter signal pin 12. Adapter ground sleeve 14 may be made of copper or other conductive material that is softer than the contact end of RF

test probe 6 in order to facilitate a good press-connection between adapter ground sleeve 14 and RF test probe 6.

Coaxial cable 8 has SMA connector 10 including barrel nut 19. Barrel nut 19 serves as the ground lead of coaxial cable 8. Adapter ground sleeve 14 has screw threads 25 adapted to engage barrel nut 19 of coaxial cable 8.

Figure 3 is an exploded close-up view of adapter 7. Adapter ground sleeve 14 has mounting flange 18. Adapter signal pin 12 has a probe contact end 20 and a cable contact end 21. At cable contact end 21, adapter signal pin 12 has hole 16 for receiving connector signal pin 30 (Figure 7) from SMA connector 10 of coaxial cable 8. Connector signal pin 30 serves as the signal lead of coaxial cable 8.

Figure 4 is a top view of adapter 7. Adapter signal pin 12 is shown inside of adapter ground sleeve 14. Mounting flange 18 has screw holes 19.

Figure 5 is a bottom view of adapter 7. Adapter signal pin 12 is shown inside of adapter ground sleeve 14.

Figure 6 is a cross-section view of adapter 7 in press-contact with RF probe 6. RF probe 6 has RF probe signal pin 27 and RF probe ground sleeve 29. RF probe signal pin 27 contacts adapter signal pin 12; RF probe ground sleeve 29 contacts adapter ground sleeve 14. RF probe signal pin 27 acts as a signal probe and RF ground sleeve 29 acts as a ground probe.

Figure 7 is a cross-section view of adapter 7 in press-contact with RF probe 6 and in screw engagement with SMA connector 10 of coaxial cable 8. SMA connector 10 has connector signal pin 30. Connector signal pin 30 is received in hole 16 at cable contact end 21 of adapter signal pin 12.

Figure 7a is a magnified view of part of Figure 7. Adapter signal pin 12 is characterized by an inner radius r_i. This is the distance from the center of adapter signal pin 12 to the outside surface of adapter signal pin 12. Ground sleeve 14 is characterized by outer radius r_o. This is the distance from the center of ground sleeve 14 to the inner surface of ground sleeve 14.

The design of adapter 7 may be adjusted to achieve a desired impedance according to the formula:

$$Z_o = \frac{\ln(r_o/r_i)\sqrt{\mu/\varepsilon}}{2\pi}$$

where μ = relative magnetic permeability of the conductor material of the adapter signal pin and the adapter ground sleeve;

ε = relative permittivity of the dielectric material;

r_i = signal pin radius;

r_o = radius of the inside surface of the ground sleeve.

For example, a dielectric material surrounding adapter signal pin 12 may be selected having a particular dielectric constant. As another example, the ratio r_o/r_i can be adjusted. As a third example, the material of adapter signal pin 12 and adapter ground sleeve 14 may be adjusted according to the same formula. Any combination of those three exemplary adjustments may be made to optimize the impedance equation for a particular application. In particular applications, adapter 7 may be designed to have an impedance of 50 ohms for use in a wireless communication environment, or an impedance of 75 ohms for use in a television environment, for example.

The sides of SMA connector 10 and/or ground sleeve 14 may have flats to facilitate assembly using a torque wrench, which creates consistent tightness and repeatable signal loss through the connections.

RF probe signal pin 27 is characterized by probe pin radius r_p. This is the distance from the center of RF probe signal pin 27 to the outer surface of RF probe signal pin 27. RF probe ground sleeve 29 is characterized by probe sleeve radius r_s. This is the distance from the center of RF probe ground sleeve 29 the inside surface of RF probe ground sleeve 29. In a preferred embodiment shown in Figure 7a, at the point where adapter 7 contacts RF probe 6, probe pin radius r_p is equal to inner radius r_i and probe sleeve radius r_s is equal to outer radius r_o.

In an exemplary application, probe pin radius r_p is smaller than the radius of connector signal pin 30 and probe sleeve radius r_s is smaller than the radius of the inside of barrel nut 19. In such a situation, as shown in Figure 7, adapter 7 provides a gradually tapered transition from the large dimensions of SMA connector 10 to the smaller dimensions of RF test probe 6 without any abrupt steps that could create reflections, signal loss, or parasitic capacitances. The taper design of adapter 7 can be changed to create smooth impedance-matched transitions between various size connectors.

Preferably, adapter 7 has the same impedance as RF probe 6 and coaxial cable 8. Maintaining the ratio r_o/r_i along the length of adapter 7, from probe contact end 20 to cable contact end 21, can ensure a consistent impedance throughout adapter 7. Thus, there is provided an adapter that connects two different size components and minimizes signal loss, reflection, and parasitic capacitances.

Figure 8 is a top view of adapter 7 mounted with screws 42 onto fixturing block 40.

Figure 9 is a bottom view of the assembly of Figure 8. Registration surfaces 44 line the underside of fixturing block 40.

Figure 10 shows the assembly of Figure 8 in contact with RF test fixture 4, RF test probe 6, and coaxial cable 8. RF test probe 6 is mounted on RF test fixture 4. Registration surfaces 44 of fixturing block 40 line up with elements (not shown) on RF test fixture 4 in order to accurately place adapter 7 in axial alignment with RF test probe 6. This arrangement exemplifies a use for adapter 7 to characterize losses associated with the test equipment of Figure 1.

Figure 11 illustrates a calibration configuration in which vector network analyzer 50 is used to characterize losses in a system without a test fixture. Vector network analyzer 50 has RF out port 52 and RF in port 54. One end of coaxial cable 3 is connected to RF out port 52. The other end has an SMA connector which contacts adapter 7 in fixturing block 40. Adapter 7 is connected to coaxial cable 8, which in turn is connected to RF in port 54.

Figure 12 illustrates a testing configuration in which vector network analyzer 50 is used to characterize losses in a system having a test fixture. Coaxial cable 3 is connected to RF out port 52 and is connected to coaxial cable 5. Thus, coaxial cable 5 is in electrical communication with RF out port 52 through coaxial cable 3. Coaxial cable 5 is fixed in test fixture 4 and is connected to RF test probe 6. RF test probe 6 is fixed in test fixture 4 and is shown in press contact with adapter 7. The position of adapter 7 is fixed by fixturing plate 40 such that adapter 7 is in axial alignment with RF test probe 6.

Adapter 7 is connected to SMA connector 10 of coaxial cable 8. Coaxial cable 8 is connected to RF in port 54.

Taken together, Figure 11, Figure 12, and Figure 1 can be used to illustrate a method exemplifying the present invention. The method comprises the following.

First, as shown in Figure 11, coaxial cable 3, adapter 7, and coaxial cable 8, all having the same impedance, are connected in series to form a calibration configuration in which adapter 7 contacts an SMA connector of coaxial cable 3. Second, a first radio frequency signal is sent through the calibration configuration illustrated in Figure 11. Third, a first loss is measured in the first radio frequency signal after the first radio frequency signal is sent through the calibration configuration of Figure 11.

Fourth, as shown in Figure 12, coaxial cable 5 and radio frequency test probe 6 are fixed in test fixture 4. Fifth, coaxial cable 3, coaxial cable 5 and radio frequency test probe 6 in test fixture 4, adapter 7, and coaxial cable 8 are connected in series to form a test configuration in which adapter 7 contacts radio frequency test probe 6. Sixth, a second radio frequency signal is sent through the test configuration shown in Figure 12. Seventh, a second loss is measured in the second radio frequency signal after the second radio frequency signal is sent through the test configuration of Figure 12.

Eighth, the first loss is subtracted from the second loss to derive a fixture loss. Knowing the fixture loss is useful when analyzing test readings for DUT 2 as described above with reference to Figure 1. Accurate characterization of loss through the test equipment ensures that the measured RF characteristics of DUT 2 are not affected by losses. That is, the losses associated with coaxial cable 5, coaxial cable 3, and radio

frequency test probe 6 in test fixture 4, are added back to the transmission and receive measurements of DUT 2 to determine the true (corrected) performance of the DUT itself.

The fourth through eighth steps may be repeated for other test fixtures. In other words, the first through fourth steps can be performed one time in order to characterize the calibration equipment consisting of coaxial cable 3, adapter 7, and coaxial cable 8. The calibration equipment may then be used to characterize accurately each of a plurality of test fixtures where each of the test fixtures has its own RF test probe fixed thereto. Once the RF signal loss attributable to the calibration equipment is known, the calibration equipment can be used repeatedly to determine the RF signal loss in any of a number of fixtures. Such fixtures can then be used to evaluate RF characteristics associated with DUTs. One such fixture is shown in Figure 1.

The above disclosure and drawings merely illustrate the inventive concepts. The skilled artisan will recognize therefrom that many variations and permutations can be made without departing from the spirit of the invention. The exemplary embodiments disclosed herein are not meant to limit the scope of the invention.